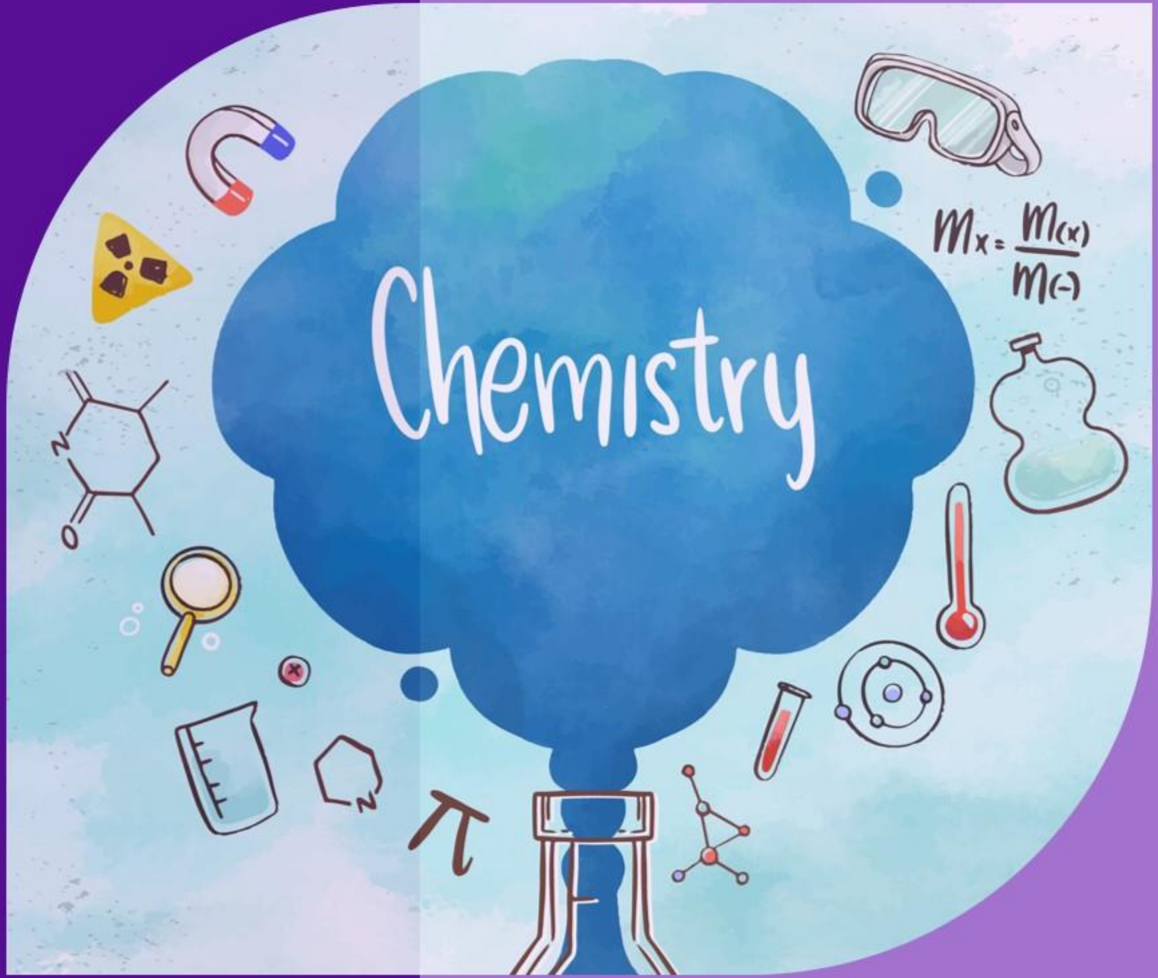
ENGINEERING ADMISSION PROGRAM 2020

CHEMISTRY

LECTURE : C-04

CHAPTER 04 : CHEMICAL EQUILIBRIUM



Atom Economy

waste

$A + B \rightarrow C \quad + D + E$

Desired product   Other generated product/ waste

$$\% \text{ AE}, = \frac{C}{\boxed{C+D+E}} \times 100$$

% AE ↑ reaction efficient ↑

$$CH_3CH_2Br + NaOH \rightarrow CH_3CH_2OH + NaBr$$

desired product

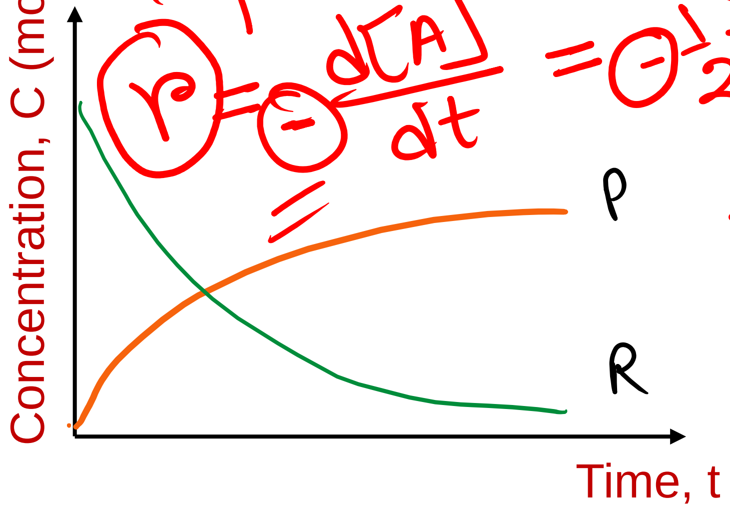
a   b

$$\% \text{ AE} = \frac{\text{mass of a}}{\text{mass of } (a+b)} \times 100\%$$

Rate of Reaction

$$A + 2B \rightarrow 3C + 4D$$

$$r = -\frac{d[A]}{dt} = -\frac{1}{2}\frac{d[B]}{dt} = +\frac{1}{3}\frac{d[C]}{dt} = +\frac{1}{4}\frac{d[D]}{dt}$$



R → P

$$rate, r = -\frac{d[R]}{dt} = +\frac{d[P]}{dt}$$

2 R → P

$$rate, r = -\frac{1}{2}\frac{d[R]}{dt} = \frac{d[P]}{dt}$$

aA + bB → cC + dD

$$rate, r = -\frac{1}{a}\frac{d[A]}{dt} = -\frac{1}{b}\frac{d[B]}{dt} = \frac{1}{c}\frac{d[C]}{dt} = \frac{1}{d}\frac{d[D]}{dt}$$

* 'C' এর rate $= \frac{d[C]}{dt}$

reaction rate w.r.t 'C' $= \frac{1}{3}\frac{d[C]}{dt}$

Problem-1

Ammonia reacts with oxygen by the given reaction-

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ at any instant, rate of reaction of ammonia is $0.24\ molL^{-1}s^{-1}$

(a) Write the rate expression for the reaction

(b) Calculate rate of generation of water. [BUET' 17-18]

$\therefore \frac{d[NH_3]}{dt} = 0.24\ molL^{-1}s^{-1}$

(a) $r = -\frac{1}{4}\frac{d[NH_3]}{dt} = -\frac{1}{5}\frac{d[O_2]}{dt} = +\frac{1}{4}\frac{d[NO]}{dt}$

$= +\frac{1}{6}\frac{d[H_2O]}{dt}$

(b) $\frac{1}{4}\frac{d[NH_3]}{dt} = \frac{1}{6}\frac{d[H_2O]}{dt} = r$

$\therefore \frac{d[H_2O]}{dt} = \frac{6}{4}\frac{d[NH_3]}{dt} = \frac{6}{4} \times 0.24 = 0.36\ molL^{-1}s^{-1}$

Factors affecting reaction rate

order

1. Concentration → ↑R → P → ROR↑↑
2. Pressure → (g) P↑ → V↓ → ROR↑↑ n
3. Surface area of reactant
4. Temperature → T↑ Ek↑ ROR↑↑
5. Catalyst
6. Nature of reactant
7. Presence of light

Arr

ROR↑↑

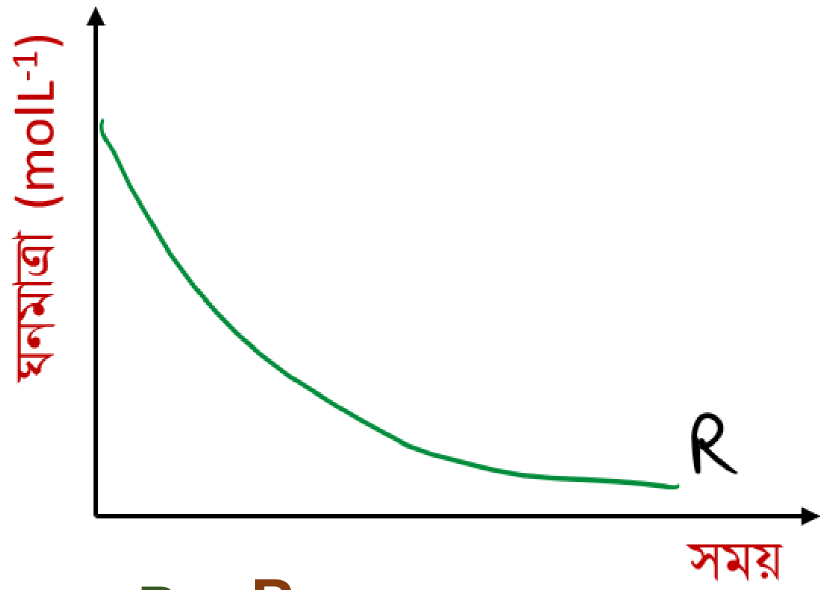
$2A \rightleftharpoons B$ P↑

$2A \rightleftharpoons 3B$ P↑ ROR↓↓

ROR↑↑

$CH_4 + Cl_2 \xrightarrow{h\nu} CH_3Cl + HCl$

Effect of Concentration; Order of Reaction:



$R \rightarrow P$

$r = f([R])$

$r \propto [R]^x$ = order

$r = k[R]^x$

$F_2 + 2ClO_2 \rightarrow 2FClO_2$

$[F_2]$/M	$[ClO_2]$/M	Initial Rate, r/Ms^{-1}
0.1	0.01	1.2×10^{-3}
0.1	0.04	4.8×10^{-3}
0.2	0.01	2.4×10^{-3}

$r = k[F_2][ClO_2]$

$r = k[F_2]^x[ClO_2]^y$

$\boxed{k, x, y}$

$aA + bB \rightarrow cC + dD$

$r = k\,(M^{1-(x+y)}s^{-1})\,[A]^x\,[B]^y$

$\boxed{n = x+y}$

Problem-2

Nitric oxide reacts with hydrogen gas to produce nitrogen and water vapor at 1280^{0}C-

2 NO (g) + H_2 (g) -> N_2 (g) + H_2O (g)

Data obtained from conducted experiments on this reaction are tabulated as follows. From this data-

(a) Calculate rate law of the reaction $\Rightarrow$ (a) $\boxed{r} = K[NO]^x[H_2]^y$

(b) Calculate the rate constant, k.

(c) Calculate rate of this reaction when [NO] = 12 x 10^{-3} M and [H_2] = 6 x 10^{-3} M

experimental value

[NO]/M	[H_2]/M	Initial Rate/Ms^{-1}
5.0 x 10^{-3}	2.0 x 10^{-3}	1.3 x 10^{-5}
10.0 x 10^{-3}	2.0 x 10^{-3}	5.0 x 10^{-5}
10.0 x 10^{-3}	4.0 x 10^{-3}	10.0 x 10^{-5}

(b) $1.3\times10^{-5} = K(5\times10^{-3})^x(2\times10^{-3})^y$ --- (i)

$5\times10^{-5} = K(10\times10^{-3})^x(2\times10^{-3})^y$ --- (ii)

$10\times10^{-5} = K(4\times10^{-3})^y(10\times10^{-3})^x$ --- (iii)

$x=2$

$y=1$

$K=$

Problem-2 (Continued)…

$x = 2$, $y = 1$, $k = \boxed{\text{Ans}}$

$r = k[NO]^x[H_2]^y$

order $= x + y$

$[NO] = 12 \times 10^{-3}$ M, $[H_2] = 6 \times 10^{-3}$ M

$\therefore r = k[NO]^2[H_2]^1$

$k =$ we know

$[NO]$

(H_2)

$r = \boxed{}$

R → P

$r = f[R]$

$r = f[R]$

Order of Reaction: 0^{th} Order Reaction

$A \rightarrow$ products

$$-\frac{d[A]}{dt} = k_0 [A]^0$$

$\Rightarrow -\frac{d[A]}{dt} = k_0 \cdot 1$

When,

t = 0, [A] = $[A]_0$

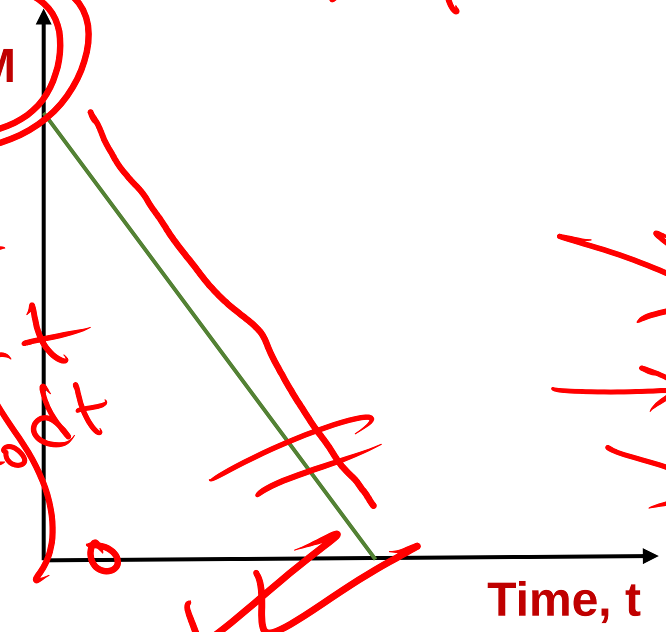
t = t, [A] = $[A]_t$

$\Rightarrow \int_{[A]_0}^{[A]_t} d[A] = -k_0 \int_0^t dt$

$A_t = -kt + A_0$

$y = mx + c$

$$\boxed{[A]_t = [A]_0 - k_0 t}$$



When,

$t = t_{1/2}$, $[A]_t = [A]_0/2$

For 0^{th} order reaction,

$$\frac{[A]_0}{2} = [A]_0 - k_0 t_{\frac{1}{2}}$$

$$t_{\frac{1}{2}} = \frac{[A]_0}{2k_0}$$

half life $t=0$ - 10 molecule

$t_{1/2} = 5$

$K = (mol L^{-1})^{1-n} s^{-1}$

n = order

Order of Reaction: 1st Order Reaction

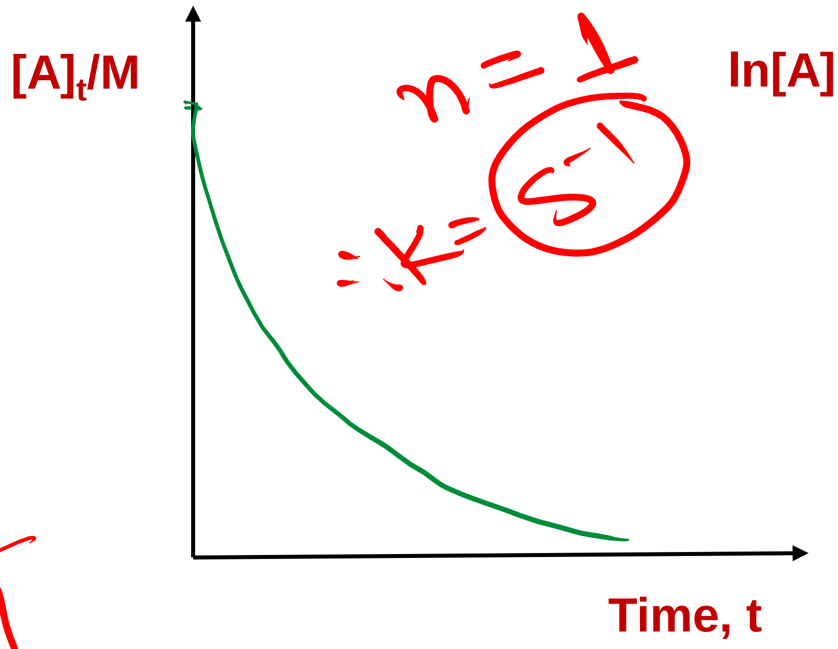
A→ products

$$-\frac{d[A]}{dt} = \mathbf{k_1\,[A]^1}$$

When,

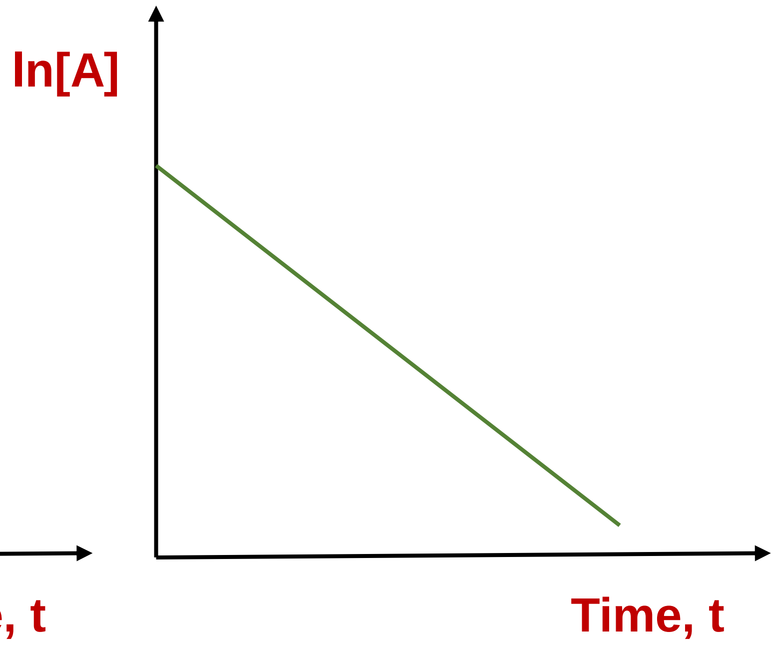
t = 0, [A] = $[A]_0$

t = t, [A] = $[A]_t$



$n = 1$

$\therefore k = (s^{-1})$



$$-\frac{d[A]}{dt} = k_1[A]$$

$$\therefore \int_{A_0}^{A_t} \frac{d[A]}{[A]} = -k\int_0^t dt$$

$$ln\frac{[A]_t}{[A]_0} = -k_1 t$$

$$[A]_t = [A]_0 e^{-k_1 t}$$

$$\ln[A]_t = ln[A]_o - k_1 t$$

Half life of reaction, $t_{1/2}$

Time required fo a single reactant reaction to sompletely converts it's 50% reactant into product(s).

$$t_{\frac{1}{2}} = \frac{ln2}{k_1}$$

A→ products

When,

$t = t_{1/2}$, $[A]_t = [A]_0/2$

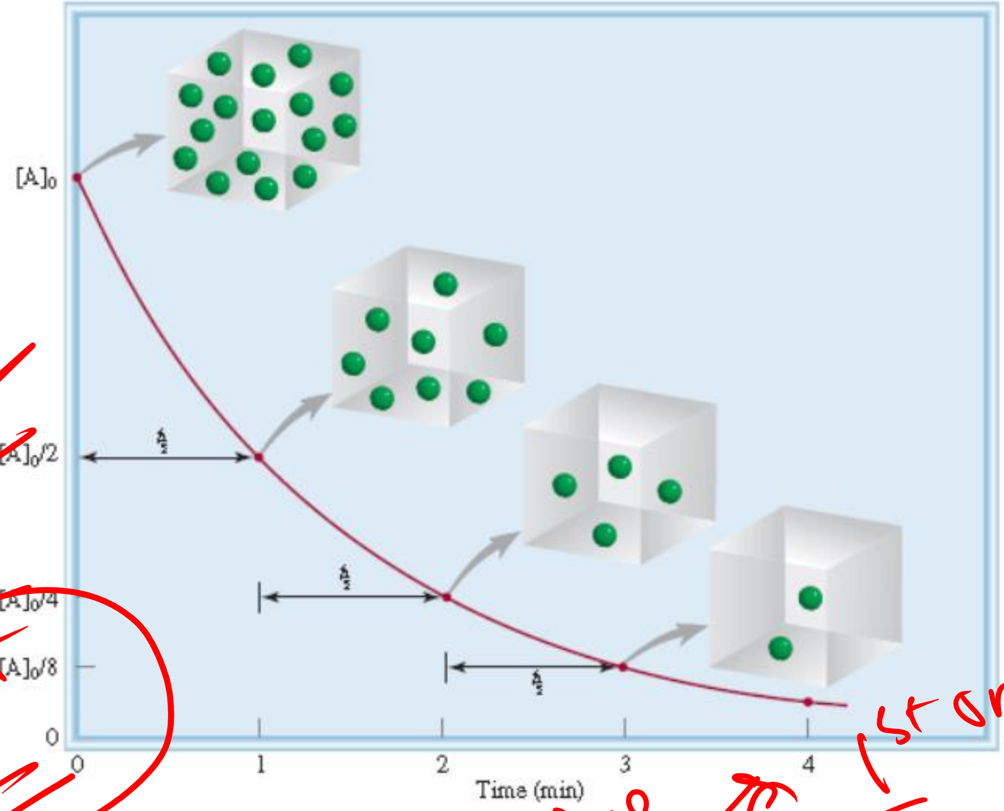
For 1st order reaction,

$$ln\frac{[A]_t}{[A]_0} = -k_1 t$$

$$ln\frac{\frac{[A]_0}{2}}{[A]_0} = -k_1 t_{\frac{1}{2}}$$

$[A]_t = [A]_0 e^{-kt}$

$N = N_0 e^{-\lambda t}$



$$t_{1/2} = \frac{ln2}{K}$$

1st order

radio active decay

$T_{1/2} = 0.693/K$

Problem-3

Rate constant for conversion of cyclopropane to propene is 6.7×10^{-4} s^{-1}. = order = 1

(a) What will be the concentration of cyclopropane after 8.8 minutes if it's initial concentration was 0.25 M?

$[A]_0 = 0.25 M$ $\quad k = 6.7 \times 10^{-4}\ s^{-1}$

(b) What time will be required to reduce the concentration of cyclopropane from 0.25 M to 0.15 M?

BUET' 17-18

$t = (8.8 \times 60)$ sec

(a) $[A]_t = [A]_0 e^{-kt} = \boxed{}$ Ans

(b) remaining concentration $= [A]_t = 0.15 M$

$[A]_t = [A]_0 e^{-kt}$

$[A]_t \to 0.15$, $[A]_0 \to 0.25$, $k \to 6.7 \times 10^{-4}$

$\therefore t = \boxed{}$

Problem-4

A one reactant system takes 40 min to convert 1/5 of it's reactant to product. order=1

(a) Calculate $t_{1/2}$ (min) of this conversion.

(b) What is the time required for 60% completion of the reaction?

(c) Calculate the time after which only 20% reactant will remain in the reaction vessel.

$[A]_t = \frac{4}{5}[A]_0$ $\qquad t = (40 \times 60)\,s$

(a) order-1 : $t_{1/2} = \frac{0.693}{K}$ $\qquad$ Ans

$[A]_t = [A]_0 e^{-Kt}$

$\frac{4}{5}A_0 = A_0 e^{-K(40 \times 60)}$

$K = \boxed{}$

Problem-4 (Continued)…

(b) 60% Complete.

$A_t = \frac{40}{100} \cdot A_0$

$K = \boxed{}$ from (a)

$t = ? = \boxed{}$

(c)

$A_t = \frac{20}{100} \times A_0$

$K =$ from (a)

$\therefore t = \boxed{}$

Order of Reaction: 2nd Order Reaction

A→ products

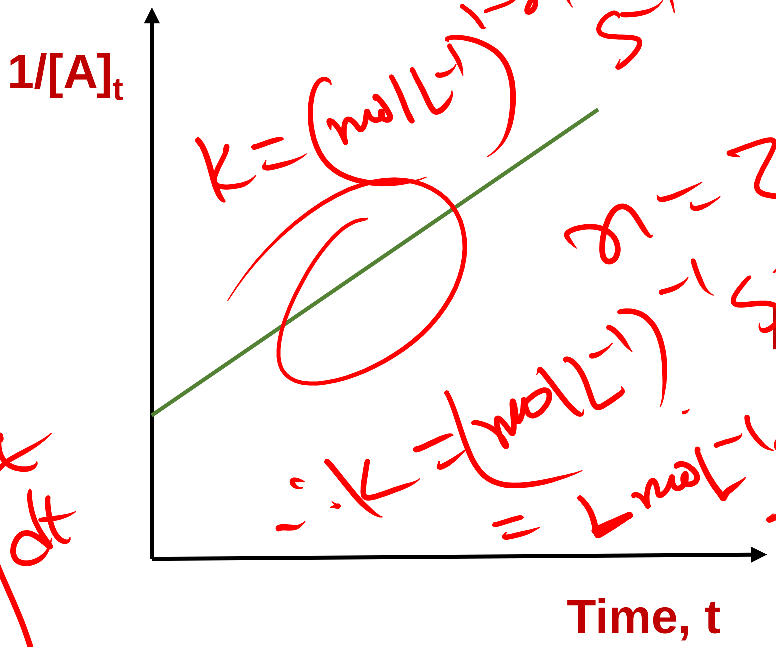
$-\frac{d[A]}{dt} = k_2 [A]^2$

$\int_{A_0}^{A_t} \frac{d[A]}{[A]^2} = -k_2 \int_0^t dt$

When,
t = 0, [A] = $[A]_0$
t = t, [A] = $[A]_t$

$$\frac{1}{[A]_t} = \frac{1}{[A]_0} + k_2 t$$

$y = c + mx$



$K = (mol\,L^{-1})^{1-n}\,s^{-1}$

$n = 2$

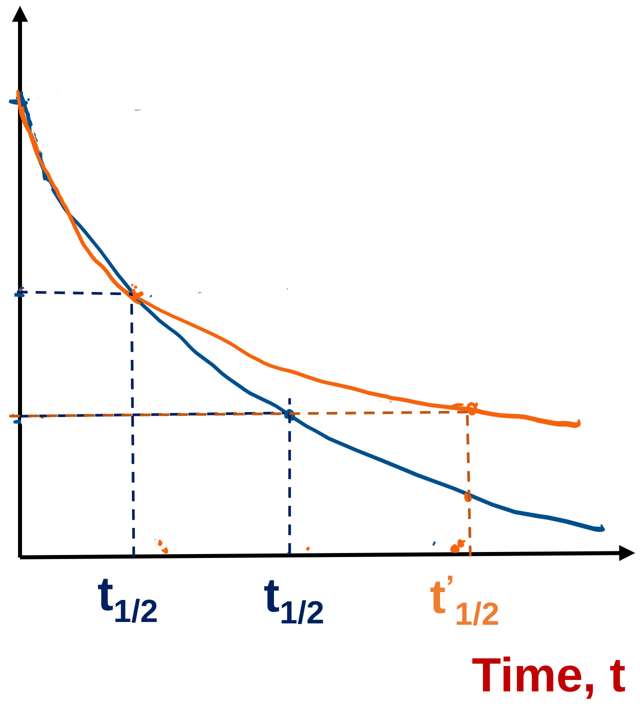
$\therefore K = (mol\,L^{-1})^{-1}\,s^{-1} = L\,mol^{-1}\,s^{-1}$

When,
$t = t_{1/2}$, $[A]_t = [A]_0/2$

For 2nd order reaction,

$$\frac{1}{\frac{[A]_0}{2}} = \frac{1}{[A]_0} + k_2 t_{\frac{1}{2}}$$

$$t_{\frac{1}{2}} = \frac{1}{k_2[A]_0}$$



Reaction Order at a glance

Order	Concentration profile	Half life, $t_{1/2}$	Straight line plot
0^{th}	$[A]_t = [A]_0 - k_0 t$	$t_{\frac{1}{2}} = \frac{[A]_0}{2k_0}$	$[A]_t = [A]_0 - k_0 t$
1^{st}	$[A]_t = [A]_0 e^{-k_1 t}$	$t_{\frac{1}{2}} = \frac{ln2}{k_1}$	$\ln[A]_t = ln[A]_o - k_1 t$
2^{nd}	$\frac{1}{[A]_t} = \frac{1}{[A]_0} + k_2 t$	$t_{\frac{1}{2}} = \frac{1}{k_2[A]_0}$	$\frac{1}{[A]_t} = \frac{1}{[A]_0} + k_2 t$

'0-2'

for further → Integrate yourself

Poll Question-1

Rate constant for an irreversible reaction was found to be 0.02 Ms^{-1}.
What is the order of the reaction?

(a) 1st order

(b) 0th order

(c) 2nd order

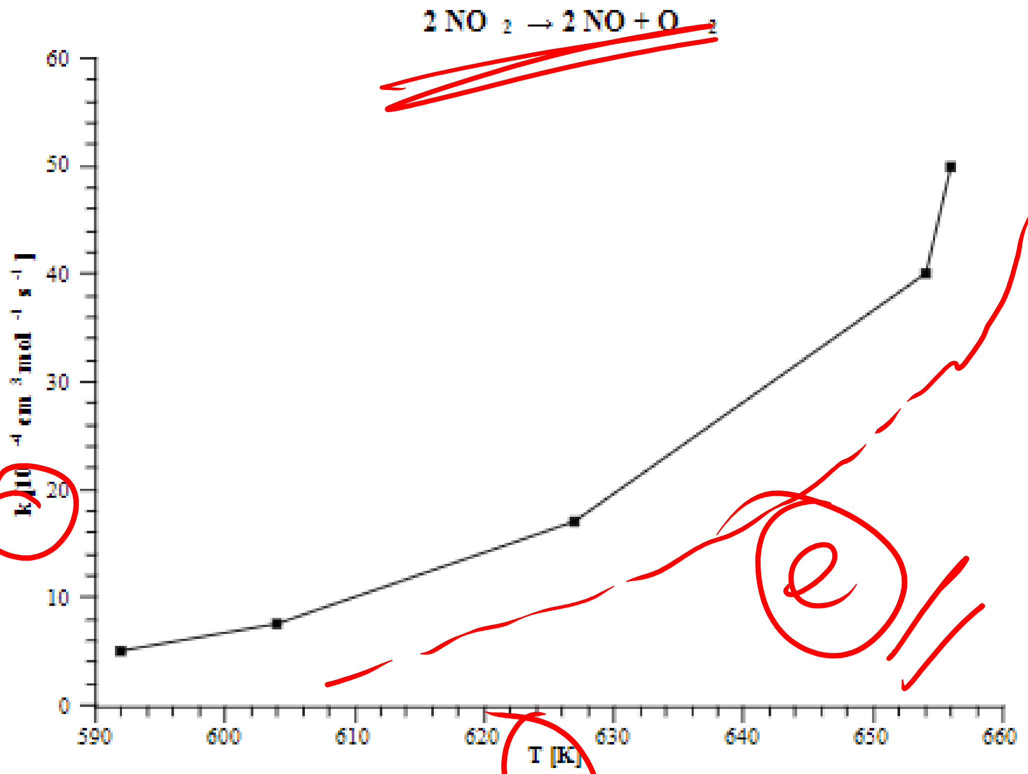
(d) 3rd order

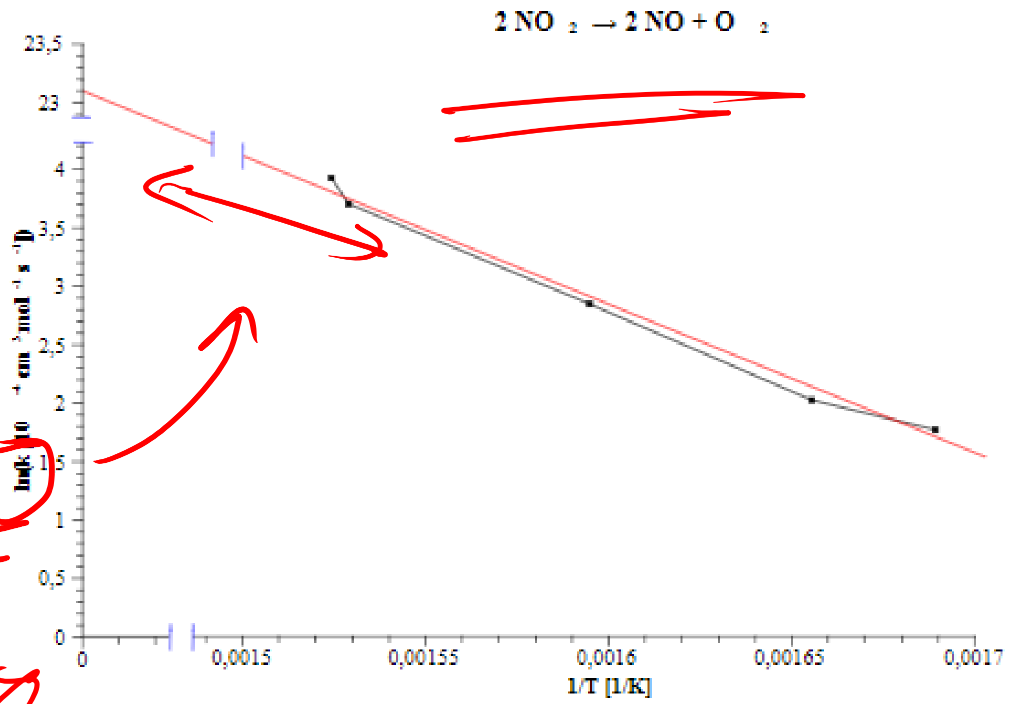
$k = (mol\,L^{-1})^{1-n}\, s^{-1}$

$Ms^{-1} = mol\,L^{-1}\,s^{-1} = (mol\,L^{-1})^{1}\,s^{-1}$

$n = 0$

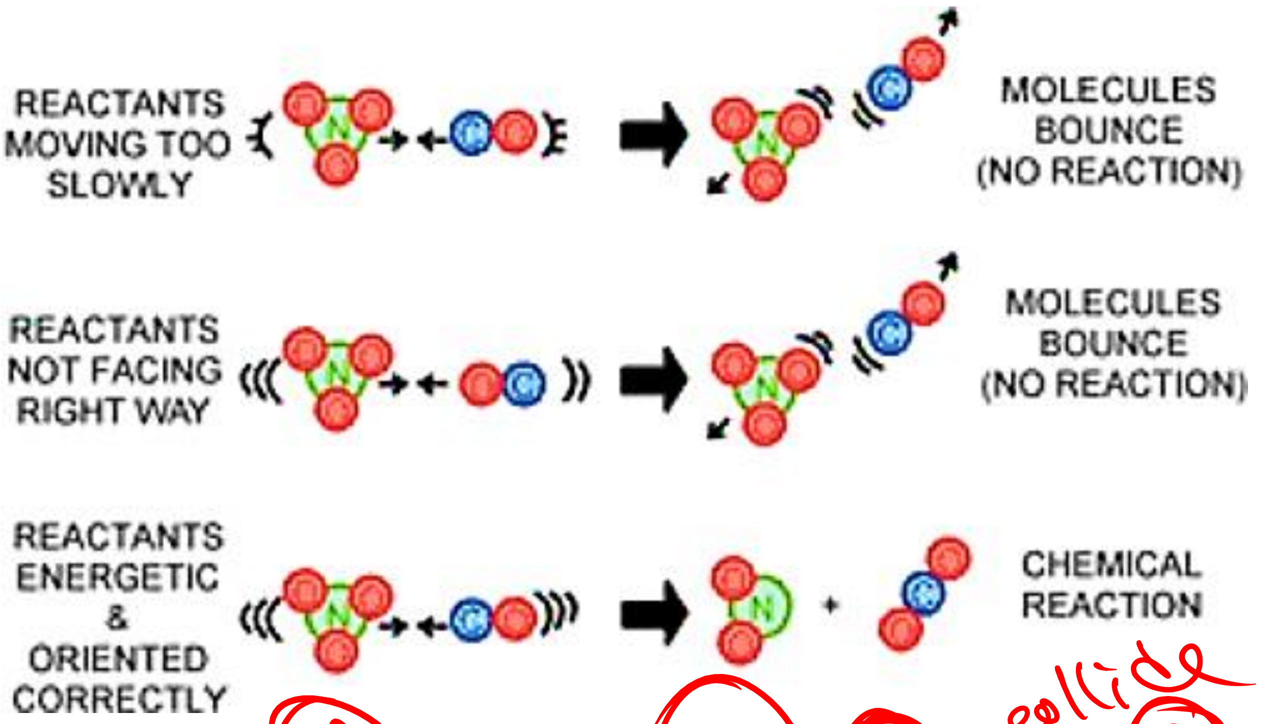
Effect of Temperature: Arrhenius Equation

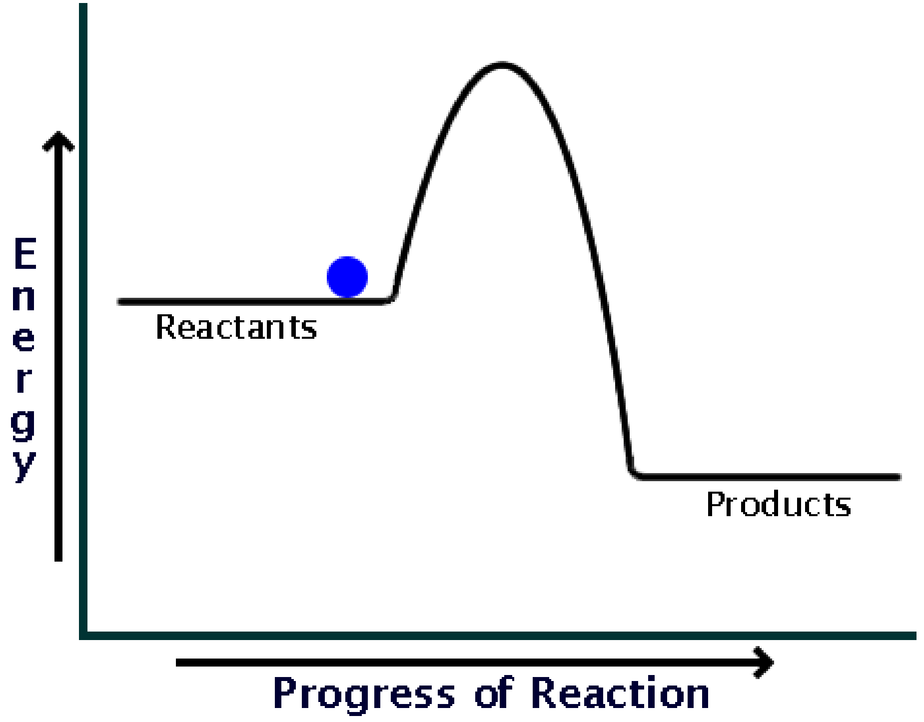




$$k = Ae^{-\frac{E_a}{RT}}$$

Collision Theory





$PZ = A$

$$k = Z\,p\,e^{-\frac{E_a}{RT}}$$

collision rate

P for steric factor $= \frac{\text{theory value}}{\text{exp. value}}$

E_a

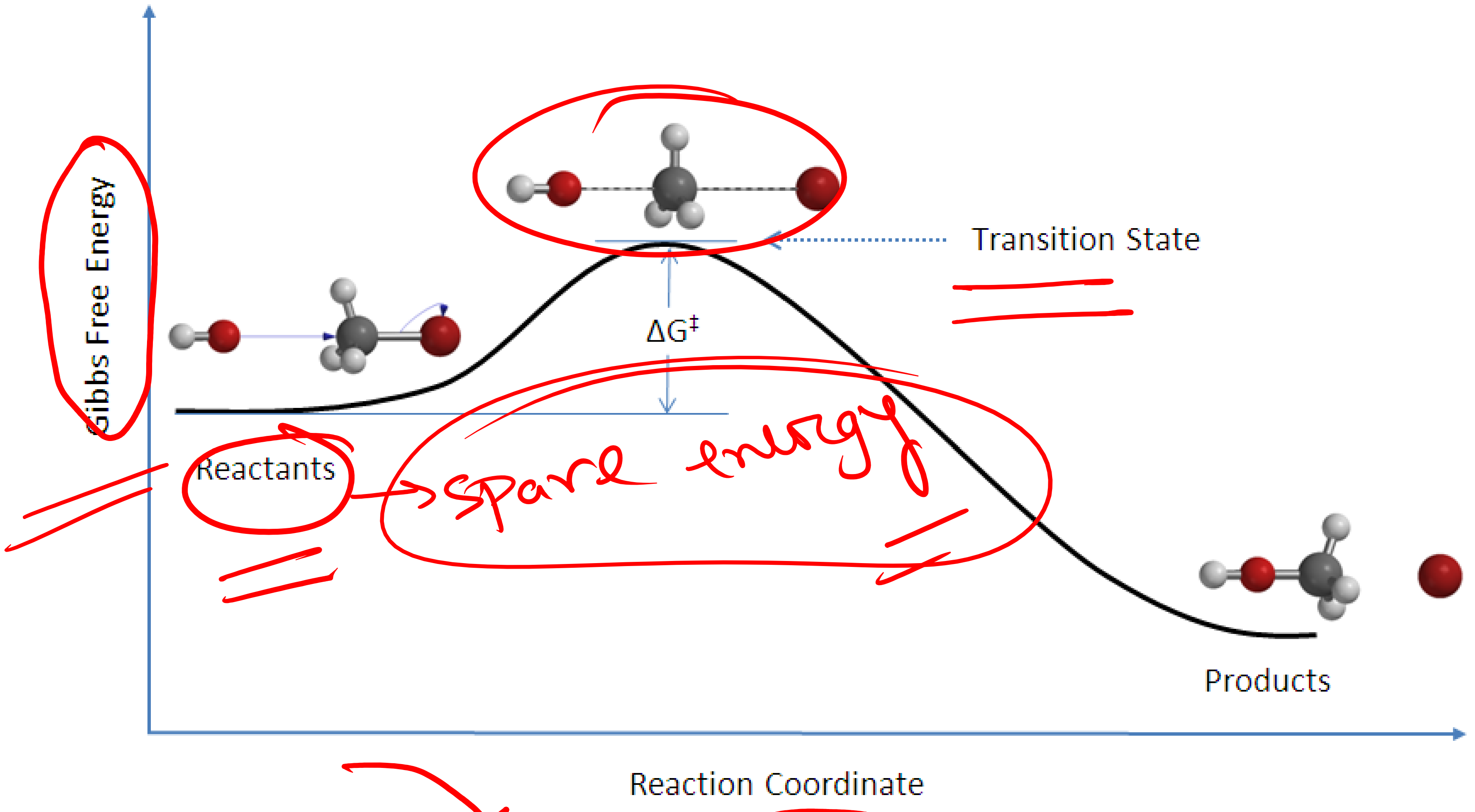
collide

i) E_a ✓

ii) steric factor

iii) collision

Transition State Theory



SN2 Reaction: $HO^- + CH_3Br \rightarrow [HO{-}{-}{-}CH_3{-}{-}{-}Br]^‡ \rightarrow CH_3OH + Br^-$

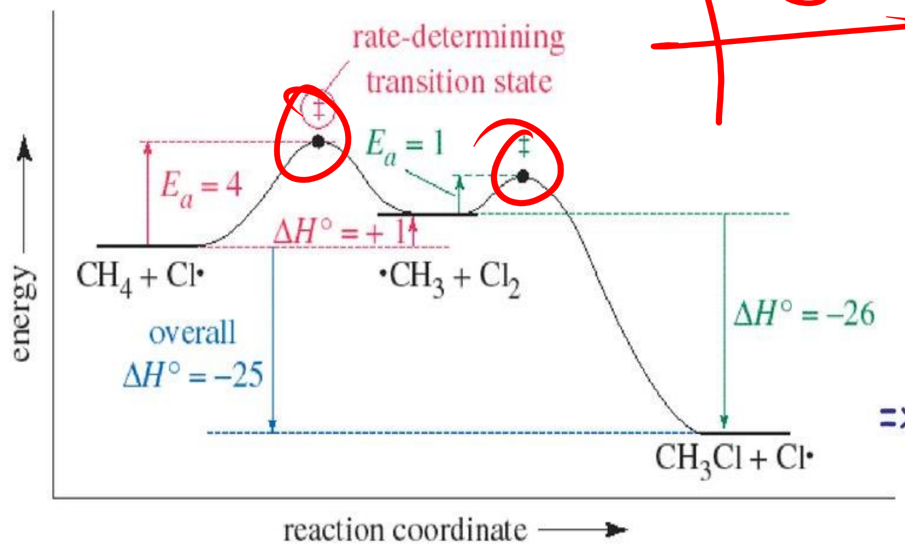
step ①

intermediate transition state

Transition State Theory

Energy Diagram for a Two-Step Reaction

- Reactants → transition state → intermediate
- Intermediate → transition state → product



=>

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

molecularity

Step-1: $Cl_2 \rightarrow 2Cl^*$ (1)

Step-2: $Cl^* + CH_4 \rightarrow CH_3^* + HCl$ (2)

Step-3: $CH_3^* + Cl_2 \rightarrow CH_3Cl + Cl^*$ (2)

Poll Question-2

The following reaction occurs in two steps. What is the molecularity of the reaction?

$$2H_2O_2(aq) \xrightarrow{I^-} 2H_2O(l) + O_2(g)$$

If it would be single step ~~then~~ more

প্রতিটি step এর জন্য particular molecularity আছে // not for whole reaction

(a) One

(b) Two

(c) Three

(d) Cannot be determined

Problem-5

Activation energy for the gas phase dissociation reaction of N_2O_5 is 103.5 $Jmol^{-1}$. Calculate the ratio of rate constants at 0^0C and 25^0C.

BUET' 13-14

$$ln\frac{k_2}{k_1} = \frac{E_a}{R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$$

$E_a = 103.5\ Jmol^{-1}$

$T_1 = 0°C = 273K$

$T_2 = 25°C = 298K$

$R = 8.314$

$\frac{k_2}{k_1} =$

Poll Question-3

Different values of rate constant of a reaction was found at different temperatures. The slope of the log k vs. 1/T graph was found to be -75 K. What was the activation energy of reaction?

(a) 1.43 $Jmol^{-1}$

(b) 1.43 $kJmol^{-1}$

(c) 14.3 $Jmol^{-1}$

(d) 14.3 $kJmol^{-1}$

$$m = -\frac{E_a}{2.303R} = -75$$

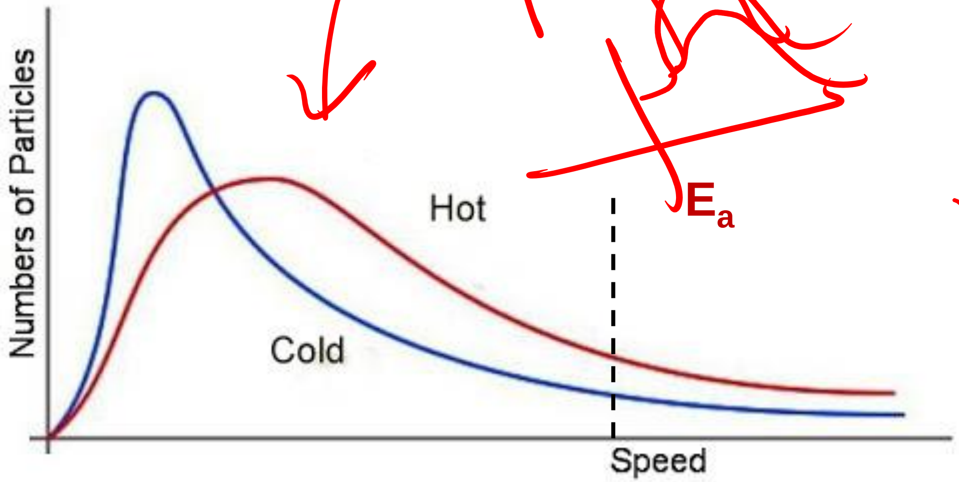
$$\therefore E_a = 75 \times R \times 2.303$$

$$= \boxed{}$$

$$R = 8.314$$

Catalyst

Catalyst is a substance that alters the rate of any chemical process but doesn’t chage it’s chemical composition* after the reaction.



1. Positive Catalyst → $E_a \downarrow$
2. Negative Catalyst → $E_a \uparrow$
3. Auto Catalyst →
4. Induced Catalyst →

$$2\,KClO_3 \xrightarrow{MnO_2} 2\,KCl + 3\,O_2$$

$$2\,H_2O_2 \xrightarrow{H_3PO_4} 2\,H_2O + O_2$$

$$5H_2C_2O_4 + 2KMnO_4 + 3\,H_2SO_4 \rightarrow 2\,MnSO_4 + 10\,CO_2 + 8H_2O$$

induced

$$2\,Na_2SO_3 + O_2 \rightarrow 2\,Na_2SO_4$$
$$Na_3AsO_3 + O_2 \rightarrow no\ reaction$$
$$(2\,Na_2SO_3 + Na_3AsO_3) + O_2 \rightarrow 2\,Na_2SO_4 + Na_3AsO_4$$

Thermochemistry

Thermodynamics:

study of dynamics of "system" due to "heat". In other words, study of "interconversion" of "heat" with other forms of "energy"

Universe

System Surrounding

Thermochemistry:

Application of “thermodynamics” to “chemical systems”

Thermodynamic Functions

State function
U, H, S, G, A etc.

Path function
q, w

Description of a System:

- Pressure, P
- Temperature, T
- Amount, n
- Volume, V

Laws of Thermodynamics

1. 0^{th} Law

2. 1^{st} Law — Change in Internal energy of a closed system is zero. — $\Delta U_{closed} = 0$

3. 2^{nd} Law — Total entropy always increases in an irreversible process. Entropy change becomes zero at equilibrium, never decreases. — $\Delta S_{univ} \geq 0$

4. 3^{rd} Law

1st Law of Thermodynamics

Entalpy, H = U + pV

Change in enthalpy, Δ H = q_P

Change in internal energy, Δ U = q_V

(Standard State)

Parameter	Standard State
Pressure	1 bar
Temperature	298 K
Matter	Pure solid/liquid

Thermochemical Equation

Reactant and product at standard state

Change in standard enthalpy

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

Δ H^0 = -890.4 $kJmol^{-1}$

$$\frac{890.4\ kJ}{1\ mol} \quad \frac{890.4\ kJ}{2\ mol} \quad \frac{890.4\ kJ}{1\ mol} \quad \frac{890.4\ kJ}{2\ mol}$$

per mole

Poll Question-4

What will be the energy released when 8.0 g of methane is completely burnt in excess oxygen at standard state?

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ → $\Delta H^0 = -890.4 \text{ kJmol}^{-1}$

16g

8 → 445.2

+

$\Delta H = -ve$

(a) 445.2 kJ

(b) 445.2 J

(c) -445.2 kJ

(d) -445.2 J

Standard Formation Enthalpy, ΔH^0_f

$aA + bB \rightarrow cC + dD$ $\Delta H^0_{reaction} = [c\,\Delta H^0_f (C) + d\,\Delta H^0_f (D)] - [a\,\Delta H^0_f (A) + b\,\Delta H^0_f (B)]$

Change in enthalpy when 1 mol of any compound is formed from its elements in standard state.

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H^0_{reaction} = \Delta H^0_f (H_2O) - [1 \times \Delta H^0_f (H_2) + 1/2\,\Delta H^0_f (O_2)]$

Def^n:
Standard formation enthalpy of elements is zero

$\Delta H^0_{reaction} = \Delta H^0_f (H_2O)$

If, $\Delta H^0_f (H_2) = 0$

$\Delta H^0_f (O_2) = 0$

0

0

Problem-6

1.0 mol methane produces 804.8 kJ of heat at 101.325 kPa constant pressure and 25^{0}C temperature when ignited with enough oxygen. Calculate heat evolved at constant volume at this temperature and pressure.

$\Delta H = 804.8 \times 10^3$ J

$\Delta H = \Delta U + P\Delta V$

at cons pressure $= \Delta H = \Delta U + P\Delta V$

$\therefore PV = nRT \Rightarrow P\Delta V = \Delta nRT$

$\therefore \Delta V = \frac{\Delta nRT}{P} = \bigcirc$

$\Delta H = \Delta U + \Delta nRT$

$\therefore \Delta U = \Delta H - \Delta nRT$

$\boxed{}$

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

$\Delta n = 1 - (1+2)$
$= -2$

$\therefore P = 101.325$ kPa
$= 101325$ Pa

$R = 8.314$

$T = 25^0C$
$= 298$K

Problem-6 (Continued)…

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

$\Delta n = 1 - (1+2) = -2$

(g)

$\Delta H = \Delta U + P\Delta V$

$= \Delta U + \Delta nRT$

$\Delta U = \Delta H - \Delta nRT$

$\therefore \Delta U = \Delta H - \Delta nRT$

$\therefore \Delta U = \boxed{}$

Problem-07

Carbon, hydrogen and sucrose ($C_6H_{12}O_6$) have standard heat of combustion values -406 kJmol^{-1}, -284 kJmol^{-1} and -5638.82 kJmol^{-1} respectively. Calculate standard formation enthalpy of sucrose.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O ; \Delta H_1 = -5638.32 \text{ kJ}$$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O ; \Delta H_2 = -284 \text{ kJmol}^{-1}$$

$$C + O_2 \rightarrow CO_2 ; \Delta H_3 = -406 \text{ kJ}$$

$$\therefore \Delta H_1 = \text{Product} - \text{reactant}$$

$$= \{6 \times \Delta H_f(CO_2) + 6 \times \Delta H_f(H_2O)\} - \{\Delta H_f(C_6H_{12}O_6) + 6\Delta H_f(O_2)\}$$

$$\Rightarrow \therefore \Delta H_f(C_6H_{12}O_6) = \{6 \times (-406) + 6 \times (-284)\} - \{-5638.82\} \text{ kJ mol}^{-1}$$

Properties of Thermochemical Equation

1. $aA \rightarrow bB; \Delta H = H_1$

   $bB \rightarrow aA; \Delta H = H_2$

   $$H_2 = -H_1$$

   Lavoisier- Laplace law

2. $aA \rightarrow bB; \Delta H = H_1$

   $naA \rightarrow nbB; \Delta H = H_2$

   $$H_2 = nH_1$$

3. $A \rightarrow B; \Delta H = H_1$

   $B \rightarrow C; \Delta H = H_2$

   $$A \rightarrow C;\ \Delta H = H_1 + H_2$$

   Hess's law

Poll Question-5

Enthalpy of the following two reactions are H_1 and H_2 respectively.

$A_2 \rightarrow 2B$ H_1

$C_2 \rightarrow B$ H_2

Find the reaction enthalpy of the following reaction.

$\frac{1}{2}A_2 \rightarrow C_2$

$+ \frac{1}{2}\Delta H_1 - \Delta H_2$

(a) $H_1 - \frac{H_2}{2}$

(b) $H_2 - \frac{H_1}{2}$

(c) $\frac{H_1}{2} - H_2$

(d) H_1-H_2

Problem-08

Calculate Lattice enthalpy of $CaCl_2$ from the given data-

(a) Heat of sublimation of Ca is H_{sub}

(b) 1^{st} ionization energy of Ca is I_1

(c) 2^{nd} ionization energy of Ca is I_2

(d) Heat of atomization of chlorine is H_{atom}

(e) Electron affinity of chlorine is EA

(f) Heat of formation of $CaCl_2$ of is H_f

Target: $Ca^{2+}(g) + 2Cl^-(g) \rightarrow CaCl_2(s)$

$\Delta H = ?$

(a) $Ca(s) \rightarrow Ca(g)$; ΔH_{sub}

(b) $Ca(g) \xrightarrow{-e^-} Ca^+(g)$; ΔH_{I_1}

(c) $Ca^+(g) \xrightarrow{-e^-} Ca^{2+}(g)$; ΔH_{I_2}

(d) $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$; ΔH_{atom}

Problem-08 (Continued)…

(e) $Cl_{(g)} + e^- \rightarrow Cl^-(g)$; ΔH_{EA}

(f) $Ca(s) + Cl_2(g) \rightarrow CaCl_2(s)$

ΔH_f

$Cl_2 \rightarrow \frac{1}{2}Cl_2(g) \rightarrow Cl(g)$

ΔH_{atom}

Problem-09

Calculate heat of the following reaction using the bond dissociation energy data given-

$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$

Bond energy of C-H = 430.532 kJmol^{-1}

Bond energy of Cl-Cl = 242.90 kJmol^{-1}

Bond energy of C-Cl = 328 kJmol^{-1}

Bond energy of H-Cl = 433 kJmol^{-1}

$H-(C-H)-H$, H $\rightarrow$ $H-C-Cl$, H, H $+ (H-Cl)$

$\Delta H = (\text{ভাঙন}) - (\text{গঠন})$

$= \{(C-H) + (Cl-Cl)\} - \{(C-Cl) + (H-Cl)\}$

kJmol^{-1}

2nd Law of Thermodynamics

$\Delta G = \Delta H - T\Delta S$

ΔG is negative; spontaneous

ΔG is positive; non-spontaneous

ΔG = 0; equilibrium

$$\Delta G = \Delta G^0 + RTlnQ$$

At equilibrium, ΔG=0, Q = K

$$\boxed{\Delta G^0 = -RTlnK}$$

reading

ΔH	ΔS	ΔG	example
+	+	- at high T	H_2O (s) -> H_2O (l)
-	-	- at low T	H_2O (g) -> H_2O (l)
+	-	Always +	$2O_3$ (g) -> $3O_2$ (g)
-	+	Always -	NaOH(s) -> Na^+(aq) + OH^- (aq)

Problem-10

Calculate the equilibrium constant for the decomposition reaction of water at 25^0C.

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$; $\Delta G = ?$

Standard free energy of element is zero and $\Delta G_f^0(H_2O) = 237.2\ kJ/mol$

$\therefore \Delta G^0 = \{2 \times \Delta G_f^0(H_2) + \Delta G_f^0(O_2)\} - \{2 \times \Delta G_f^0(H_2O)\} = -2 \times 237.2\ kJ\ mol^{-1}$

$R = 8.314$

$T = 298$

ΔG^0

$\therefore \Delta G^0 = -RT\ln K$

$\therefore K = \boxed{}$

লেগে থাকো সৎ ভাবে,
স্বপ্ন জয় তোমারই হবে।